CLAIMS

What is claimed is:

1. An attenuating phase shift mask blank for use in lithography comprising:

substrate;

a phase shifting layer disposed on said substrate;

said phase shifting layer comprising a surface layer rich in oxygen;

said phase shift mask blank is capable of producing a photomask with substantially 180° phase shift and an optical transmission of at least 0.001% at a selected wavelength of <500nm.

2. An attenuated phase shift mask blank according to claim 1 wherein the phase shifting layer comprises a composite material of formula $A_wB_xN_yO_z$, where A is an element selected from the group consisting of Groups IVA, VA, or VIA; and B is selected from the group consisting of an element from Groups II, IV, V, the transition metals, the lanthanides and the actinides; wherein w is in a range between 0.1 and 0.6, x is in a range between 0.01 and 0.2 , y is in a range between 0 and 0.6, and z is in a range between 0 and 0.7.

3. An attenuated phase shift mask blank according to claim 1 wherein the phase shifting layer comprises a material selected from the group consisting of a silicon/ titanium/nitrogen composite and a silicon/titanium/nitrogen/oxygen composite.

4. An attenuated phase shift mask blank according to claim 3 wherein said silicon/titanium/nitrogen composite has structural formula $Si_wTi_xN_y$ wherein w = 0.1~0.6, x = 0.01~0.2, y = 0.3~0.6.

5. An attenuating phase shift mask blank according to claim 3 wherein said silicon/titanium/nitrogen/oxygen composite has structural formula $Si_wTi_xN_yO_z$ wherein w = 0.1~0.6, x = 0.01~0.2, y = 0~0.6, and z=0~0.7.

6. An attenuating phase shift mask blank according to claim 1, wherein the phase shifting layer has a thickness of from about 400 Å to about 2000 Å wherein said surface layer rich in oxygen has a thickness of from about 10 Å to about 150 Å.

7. A method of fabricating an attenuating phase shift mask blank for use in lithography comprising:

providing a substrate;

disposing a thin layer of phase shifting layer on said substrate;

forming a surface layer rich in oxygen on said phase shifting layer;

wherein said blank is capable of producing a photomask with 180° phase shift and an optical transmission of at least 0.001 % at a selected wavelenth of <500nm.

8. A method according to claim 7 wherein the phase shifting layer comprises a composite material of formula $A_wB_xN_yO_z$, where A is an element selected from the group consisting of Groups IVA, VA, or VIA; and B is selected from the group consisting of an element from Groups II, IV, V, the transition metals, the lanthanides and the actinides; wherein w is in a range between 0.1 and 0.6, x is in a range between 0.01 and 0.2, y is in a range between 0 and 0.6, and z is in a range between 0 and 0.7 .

9. A method according to claim 7 wherein the phase shifting layer comprises a material selected from the group consisting of a silicon/titanium/nitrogen composite and a silicon/titanium/nitrogen/oxygen composite.

10. A method according to claim 9 wherein said silicon/titanium/nitrogen composite has structural formula $Si_wTi_xN_y$ wherein w = 0.1~0.6, x = 0.01~0.2, y = 0.3~0.6, z =0~0.7.

11. A method according to claim 9 wherein said silicon/titanium/nitrogen/oxygen composite has structural formula $Si_wTi_xN_yO_z$ wherein w = 0.1~0.6, x = 0.01~0.2, y = 0~0.6, and z=0~0.7.

12. A method according to claim 7 wherein the phase shifting layer is formed by sputter deposition from a target of a composite material ($Si_{1-x}Ti_x$) wherein x=0.01~0.5 by a method selected from the group consisting of RF matching network, DC magnetron, AC magnetron, pulsed bipolar DC magnetron and RF diode.

13. A method according to claim 12 wherein the substrate is disposed in a holder which can be either planetary or stationary and/or rotating or non-rotating.

14. A method according to claim 8 wherein the phase shifting layer is formed by sputter deposition from a target of a composite material ($Si_{1-x}Ti_x$) wherein x=0.01~0.5 by a method selected from the group consisting of RF matching network, DC magnetron, AC magnetron, pulsed bipolar DC magnetron and RF diode.

15. A method according to claim 14 wherein the substrate is disposed in a holder which can be either planetary or stationary and/or rotating or non-rotating.

16. A method according to claim 9 wherein the phase shifting layer is formed by sputter deposition from a target of a composite material ($Si_{1-x}Ti_x$) wherein x=0.01~0.5 by

a method selected from the group consisting of RF matching network, DC magnetron, AC magnetron, pulsed bipolar DC magnetron and RF diode.

17. A method according to claim 16 wherein the substrate is disposed in a holder which can be either planetary or stationary and/or rotating or non-rotating.

18. A method according to claim 7 wherein the phase shifting layer is formed by sputter deposition from two or more targets of different compositions using a technique selected from the group consisting of RF matching network, DC magnetron, AC magnetron, pulsed bipolar DC magnetron and RF diode.

19. A method according to claim 18 wherein said two or more targets are selected from the group consisting of Si_3N_4 and Ti targets, or $(Si_{1-x}Ti_x)$ wherein x=0.01~0.5 and Ti targets.

20. A method according to claim 18 wherein the substrate is disposed in a holder which can be either planetary or stationary and/or rotating or non-rotating.

21. A method according to claim 8 wherein the phase shifting film is formed by sputter deposition from two or more targets of different compositions using a technique selected from the group consisting of RF matching network, DC magnetron, AC magnetron, pulsed bipolar DC magnetron and RF diode.

22. A method according to claim 21 wherein said two or more targets are selected from the group consisting of Si_3N_4 and Ti targets, or $(Si_{1-x}Ti_x)$ wherein x=0.01~0.5 and Ti targets.

23. A method according to claim 21 wherein the substrate is disposed in a holder which can be either planetary or stationary and/or rotating or non-rotating.

24. A method according to claim 9 wherein the phase shifting layer is formed by sputter deposition from two or more targets of different compositions using a technique selected from the group consisting of RF matching network, DC magnetron, AC magnetron, pulsed bipolar DC magnetron or RF diode.

25. A method according to claim 24 wherein said two or more targets are selected from the group consisting of Si_3N_4 and Ti targets, or $(Si_{1-x}Ti_x)$ wherein x=0.01~0.5 and Ti targets.

26. A method according to claim 24 wherein the substrate is disposed in a holder which can be either planetary or stationary and/or rotating or non-rotating.

27. A method according to claim 7 wherein structural changes occur in said phase shifting layer to stabilize against radiation and chemical treatment by including an increased surface oxygen concentration to form said surface layer rich in oxygen which is obtained by annealing at elevated temperature in an atmosphere selected from the group consisting of air, oxygen, vacuum and a mixture of gases selected from the group consisting of O_2, N_2, H_2, Ar, Kr, Ne, He, O_3 and H_2O.

28. A method according to claim 8 wherein structural changes occur in said phase shifting layer to stabilize against radiation and chemical treatment by including an increased surface oxygen concentration to form said surface layer rich in oxygen which is obtained by annealing at elevated temperature in an atmosphere selected from the group consisting of air, oxygen, vacuum and a mixture of gases selected from the group consisting of O_2, N_2, H_2, Ar, Kr, Ne, He, O_3 and H_2O.

29. A method according to claim 9 wherein structural changes occur in said phase shifting layer to stabilize against radiation and chemical treatment by including an increased surface oxygen concentration to form said surface layer rich in oxygen which is obtained by annealing at elevated temperature in an atmosphere selected from the

group consisting of air, oxygen, vacuum and a mixture of gases selected from the group consisting of O_2, N_2, H_2, Ar, Kr, Ne, He, O_3 and H_2O.

30. A method according to claim 7 wherein the annealing can be done by using methods selected from the group consisting of laser annealing, plasma annealing, thermal annealing, microwave annealing and radiation treatment.

31. A method according to claim 8 wherein the annealing can be done by using methods selected from the group consisting of laser annealing, plasma annealing, thermal annealing, microwave annealing and radiation treatment.

32. A method according to claim 9 wherein the annealing can be done by using methods selected from the group consisting of laser annealing, plasma annealing, thermal annealing, microwave annealing and radiation treatment.

33. A method according to claim 7 wherein the surface layer rich in oxygen is obtained by oxygen plasma bombardment.

34. A method according to claim 8 wherein the surface layer rich in oxygen is obtained by oxygen plasma bombardment.

35. A method according to claim 9 wherein the surface layer rich in oxygen is obtained by oxygen plasma bombardment.

36. A method according to claim 7 wherein an oxygen partial pressure of the process gas during deposition is increased at the final stage of deposition.

37. A method according to claim 8 wherein an oxygen partial pressure of the process gas during deposition is increased at the final stage of deposition.

38. A method according to claim 9 wherein an oxygen partial pressure of the process gas during deposition is increased at the final stage of deposition.

39. A method according to claim 7 wherein the sputter target is made by hot isostatic pressing. .

40. A method according to claim 8 wherein the sputter target is made by hot isostatic pressing.

41. A method according to claim 9 wherein the sputter target is made by hot isostatic pressing.

42. A method according to claim 7 wherein the sputter target is made of a mixture of metal silicide and silicon.

43. A method according to claim 8 wherein the sputter target is made of a mixture of metal silicide and silicon.

44. A method according to claim 9 wherein the sputter target is made of a mixture of metal silicide and silicon.

45. A method according to claim 7 wherein the sputter target is made of a mixture of titanium silicide and silicon.

46. A method according to claim 8 wherein the sputter target is made of a mixture of titanium silicide and silicon.

47. A method according to claim 9 wherein the sputter target is made of a mixture of titanium silicide and silicon.